An Overall Framework for Personalised Landmark Selection

Eva Nuhn and Sabine Timpf

Abstract This paper proposes a multidimensional model for the selection of personalized landmarks. The model is based on an existing landmark salience model, which was designed to be open to adaptations regarding individual user preferences. The conventional model is based solely on landmark dimensions (i.e. visual, semantic and structural dimension). We add an additional personal dimension to account for different familiarities and interests. Further, we add an environmental dimension to accommodate different routing situations and a descriptive dimension to consider the brevity of a landmark description. In this paper we identify the attributes of the dimensions of the multidimensional model and investigate methods for calculating the salience of the attributes. The applicability and usefulness of the (still evolving) model is shown with three different case studies.

1 Introduction

Awareness has been increasing that people with different backgrounds and preferences prefer different landmarks (Hamburger and Röser 2014; Quesnot and Roche 2015). The latter study showed that people familiar with an environment clearly preferred local semantic landmarks, while people unfamiliar with an environment preferred landmarks with salient visual and structural characteristics. It is also known that the level of interest can enhance memory for some information (McGillivray et al. 2015). Obviously, it is a challenging task to find the best landmark based on spatial knowledge and individual interests of a traveler.

The term landmark exhibits many different meanings. The most fundamental one is that of an object or structure that serves as external point of reference (Lynch 1960). Thus, a landmark has an outstanding visual characteristic, a unique importance

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P. Kiefer et al. (eds.), *Progress in Location Based Services 2018*, Lecture Notes in Geoinformation and Cartography, https://doi.org/10.1007/978-3-319-71470-7_12

or meaning or is in a central location (Sorrows and Hirtle 1999). Landmark salience is additionally affected by the perspective of the observer, the surrounding environment and the objects contained therein (Caduff and Timpf 2008). For the purpose of this study, we are defining the term landmark as "any outstanding urban structure". We do not restrict our work to buildings and treat also other urban structures (e.g. water wheels, information panels or dust bins). We focus on three-dimensional local landmarks for pedestrians at decision points.

There is a large number of possible landmarks, which can be included in route instructions in different situations and for different travelers. Different travelers would find different landmarks to be most useful in a given situation (Götze and Boye 2016). Humans choose landmarks based on several criteria, such as the mode of travel, the desired route characteristics (Lovelace et al. 1999) but also using personal dimensions. Several studies have proposed landmark salience models. These models are either typically *landmark identification* or *landmark integration* models (Richter and Winter 2014). *Landmark identification* models are based on landmark dimensions and identify landmarks' salience based on the well-established visual, semantic and structural dimensions by Sorrows and Hirtle (1999). The degree to which each of these dimensions influences the total measure of landmark salience is determined using weights for each dimension. How these weights should be chosen to adapt to the mode of travel or individual user preferences has not yet been studied extensively. *Landmark integration* models by contrast are based on environmental dimensions. They detect route-dependent landmarks according to attributes such as uniqueness in a given environment, position along a route or visibility from the route. None of the models investigated so far include personal preferences or knowledge that influence the process of landmark integration.

The contribution of this paper is a multidimensional model that helps to select personalized landmarks. The goal is to extend an existing landmark salience model by including a so called personal dimension of landmarks. Specifically, we take the existing landmark salience model by Raubal and Winter (2002) and add personal attributes. Furthermore, we add an environmental dimension to account for different routing situations and a descriptive dimension to consider the brevity of a landmark description. The result of the model is a measure of the personal landmark salience of a landmark candidate for a specific person. The measure can then be integrated in the generation of a route (Nuhn and Timpf 2016). This paper tackles the challenges of designing such a multidimensional model, while the integration of the results in routing algorithms is treated elsewhere.

Section 2 gives an overview of related work, focusing on existing landmark salience models based on landmark, descriptive, environmental as well as personal dimensions. Section 3 introduces the multidimensional model for personalized landmarks. In Sect. 4 we present example case studies to demonstrate the proposed model. The final section concludes and identifies future work.

2 Related Work

In this section existing work regarding landmark salience models based on landmark, descriptive, environmental and personal dimensions is reviewed.

Landmark Dimensions

In landmark research *landmark identification* is done considering several dimensions of landmarks. A classification was presented by Sorrows and Hirtle (1999) and modified by Raubal and Winter (2002). The framework defines three landmark dimensions: the visual, the semantic and the structural dimension. There are many approaches based on these landmark dimensions to assess the salience of objects for route instructions. One very fundamental approach was proposed by Raubal and Winter (2002). They suggested measures to formally specify the salience of buildings (see Sect. 3.3.1). Nothegger et al. (2004) further extended and implemented the approach on façades and showed that the model is applicable to assessing landmark salience. Elias (2003) was the first to propose data mining methods: She used existing spatial databases instead of manual collection methods and thus focused on buildings as landmark candidates.

There are other studies addressing the lack of available data sources. Newer approaches are based on VGI (Volunteered Geographic Information) and crowdsourcing initiatives. For example Kattenbeck (2016) proposed an empirically validated model and approach for a survey-based assessment of object salience. The model incorporates the results of prior studies on features that are important for salience. After testing the model with a large-scale in-situ experiment it turned out that route related features as well as visual aspects are the most important influences for the prediction of the overall salience of a feature. Another approach used Open Street Map (OSM) data as source and implemented tagging OSM objects as potential landmarks (Wolfensberger and Richter 2015). They implemented a mobile application, which enables user-generated collection of landmarks. Other approaches used OSM data to automatically identify landmarks. Nuhn et al. (2012) proposed a landmark index based on attributes of the landmark dimension to automatically extract landmarks from OSM. These approaches can be used to provide methods for real-world crowd sourcing scenarios, which are important for mobile pedestrian navigation systems. However, all approaches have in common that they only consider attributes contributing to the landmark dimension.

Descriptive Dimensions

The brevity of a landmark description relates to the number of words or terms needed to refer to it in route instructions (Burnett et al. 2001). The description of a landmark should be as precise as possible. According to Burnett et al. (2001) a good landmark requires a minimum of additional information to be usable in route instructions. A detailed description of an object can prevent confusion with other objects but the complexity of the description should be minimized to reduce the cognitive load (Elias 2003). Too much information has an adverse effect on efficient wayfinding (Schneider and Taylor 1999). Objects with lengthy descriptions require the wayfinder to process several different information elements (Burnett et al. 2001). The length of the landmark description can vary depending on the perspective and the familiarity of the traveler with the environment. A description can be coarse such as “the church”, but it can also be refined in various ways (e.g. “the church with the red façade and the two steeples”) (Tenbrink and Winter 2009).

Environmental Dimensions

Approaches that focus on environmental dimensions are known as *landmark integration* approaches (Richter and Winter 2014). Here the focus is on environmental attributes (e.g. distance to the decision point, visibility from the route or uniqueness in the neighborhood of the route). The *advance visibility* of an object informs if the object can be clearly seen from the route in all conditions (Burnett et al. 2001). Winter (2003) introduced advance visibility into the basic model of Raubal and Winter (2002). He investigated the identifiability of an object along the route, taking into account that a geographic feature that is visible early on along a route is more suitable as a landmark than a feature that is spotted at the very last moment. Klippel and Winter (2005) also integrated landmarks in route instructions with regard to a specific route. Besides advance visibility they considered the configuration of the street network as well as the route along the network. An approach to integrate landmark information directly into the routing algorithm was proposed by Elias and Sester (2006) using a modified Dijkstra algorithm to calculate an optimal route based on landmark quality. Weights were adapted according to the permanence, visibility, usefulness of location, uniqueness and brevity of the landmark description. In a similar fashion the Landmark-Spider-Algorithm from Caduff and Timpf (2005) calculates the clearest route in terms of spatial references and uses selected landmarks to give route instructions. The model selects landmarks based on distance and orientation of the traveler with respect to the landmark and salience of the objects. Another approach which uses types of landmarks tackles the incorporation of landmarks in computer-generated route instructions (Duckham et al. 2010). Here a weighting system is proposed that is based on expected average properties of the types of landmarks (e.g. ubiquity, length of description, permanence...). Those objects are determined that are best suited to describe how to follow a given route.

Personal Dimensions

The landmark salience of an object is not only dependent on landmark or environmental attributes but also on personal dimensions. Different travelers would find different landmarks to be the most useful ones in a given situation (Götze and Boye 2016). The landmarkness of an object is dependent on mobility, gender, age, education or hometown of the traveler (Winter et al. 2012). There is only little work that deals with the idea that salience is not the same for every person. Burnett et al. (2001) were the first who showed that travelers familiar with an environment choose other landmarks than people unfamiliar with an environment. More recent studies confirmed their findings and showed that familiar buildings are more easily recognized than unfamiliar ones (Hamburger and Röser 2014). Based on these results Quesnot and Roche (2015) assumed that travelers who know the area by heart prefer different landmarks than travelers unfamiliar with an environment. They confirmed this assumption and showed that persons that are familiar with a specific environment prefer landmarks with personal significance.

Balaban et al. (2014) showed that emotions may have an influence on landmark selection as well. They showed that negatively laden landmarks are remembered better than positively laden or neutral ones. In addition, Palmiero and Piccardi (2017) showed that both positive and negative emotional landmarks equally enhance the ability to learn a path, and thus influence the acquisition of spatial knowledge. Furthermore, they found that positive emotional landmarks improved the reproduction of a path on the map as compared to negative or neutral emotional landmarks. The investigation of emotions and landmarks is also a personalization, which however neglects other personal dimensions. Götze and Boye (2016) model every landmark that a person refers to in route instructions as a vector of features. Then an individual mathematical model of salience is derived for every person. Currently this approach is restricted to landmark dimensions, since the feature vectors only include spatial attributes (distance and angle to a landmark as well as name and type extracted from OSM data).

An approach to adapt the model by Raubal and Winter (2002) to different contexts was proposed by Winter et al. (2005) by modeling the weights of the salience measures. In addition they investigated the proposed method in a thorough human subject test and found evidence that the variation of the context changes the selection of the landmarks. However, their work focused on weights based on different contexts (here, the time of the day). Apart from gender differences in weighting landmarks by day and by night no other attributes of the personal dimension were investigated. Although the familiarity with the environment was collected from test persons on a simple binary scale, this attribute was not further evaluated. In our work we focus on additional fundamental attributes of the personal dimension to provide help for the automatic selection of personalized landmarks.

3 The Multidimensional Model for Personalized Landmarks

In this section we introduce our multidimensional model for personalized landmarks. In a first step the dimensions of the multidimensional model are discussed. Then the saliences of all attributes are calculated. In a final step the overall salience of a landmark is calculated using the model from Raubal and Winter (2002) and compared to our extended multidimensional model.

3.1 Dimensions of the Multidimensional Model

In this section we identify, investigate and discuss the attributes of the dimensions of the multidimensional model.

3.1.1 Landmark Dimensions

We follow the preceding definitions of Sorrows and Hirtle (1999) and Raubal and Winter (2002) for the landmark dimensions.

Visual Dimension
Our multidimensional model includes four attributes for the visual dimension. One of them is the *surface structure*. Buildings are visually salient if they have e.g., bay windows or balconies. Other objects are salient if they are not shaped uniformly (e.g. a water wheel with its blades is salient). An object with a differently shaped roof than all the others within an environment (e.g. a street light with a peaked "roof") has a salient *surface area*, which is another visual attribute. An object can also be outstanding because of the visual attribute *height* (e.g. a city gate is higher than all the other objects around it). Another attribute of the visual dimension is *color*. For example, multicolored recycling bins in a street with houses with no outstanding coloring can attract the traveler's attention.

Semantic Dimension
We calculate semantic salience by taking into account the *cultural* and *historical importance*. Culturally important objects are for example museums, sports centers or cinemas. Objects with historical importance are city walls or historic buildings. In addition we investigate if *explicit marks* are available, because objects showing explicit marks specify their semantics to the traveler (Raubal and Winter 2002) and are therefore easy to identify.

Structural Dimension
Following Raubal and Winter (2002) we focus on local landmarks for wayfinding, thus we include only local structural elements. The *number of adjacent routes* gives information if the object is located at a street intersection. Such objects are more important for route instructions than objects not connected to a street intersection. The *number of adjacent objects* shows if the object is freestanding or not. Freestanding objects (e.g. a city light) are more salient than objects that are part of an assembly (e.g. terraced houses).

3.1.2 Descriptive Dimension

The descriptive dimension has not been considered in the work of Raubal and Winter (2002). We propose to use *explicit marks* and *number of words* as attributes. An object with an *explicit mark* can be explicitly named within route instructions. Further, the traveler can easily identify the intended object. Thus, an explicit mark is very valuable and can be directly used in route instructions. Furthermore, the *number of words* is an important attribute for the descriptive dimension. It can be assumed that the reference to a "long elongated blue building" needs more working memory than the simple reference to the "casino" (Schneider and Taylor 1999).

3.1.3 Environmental Dimension

There are several studies (see Sect. 2) proposing several environmental attributes. Based on that our multidimensional model includes *advance visibility*, *orientation*, *distance* and *uniqueness*. *Advance visibility* for a person approaching a decision point is a cognitively relevant factor for the determination of landmarks (Winter 2003). To consider the *orientation* of an object to the traveler the geographical space is divided into sections (i.e. in front, beside and behind). The sections are dependent on the traveler's heading which corresponds to the orientation of the route segment leading to the decision point. Objects close to a decision point are useful for navigation purposes (Waller et al. 2000). Thus, we consider the *distance* to the decision point as attribute of the environmental dimension. Landmarks which are not *unique* can be mistaken with other objects within the environment. Therefore we investigate the neighboring street intersections if there are similar misleading objects.

3.1.4 Personal Dimensions

In a former work we identified personal dimensions to consider in determining personalized landmarks (Nuhn and Timpf 2017). Based on that we include the personal dimensions *prior spatial knowledge*, *personal interests* and *personal background* in our multidimensional model.

Prior Spatial Knowledge

The prior spatial knowledge of a traveler seems to be the most important dimension to consider. It is commonly divided into three distinct types: landmark knowledge, route knowledge and survey knowledge (Siegel and White 1975). In Nuhn and Timpf (2017) we introduced four attributes to consider the prior spatial knowledge of a traveler: no knowledge, landmark knowledge, route knowledge and survey knowledge. While traveling through the environment people notice various objects and encode images in a database. Thus, people are able to recall the objects they have seen and to remember the names of certain buildings and locations (Thorndyke 1980). These *landmark knowledge* landmarks can be used within route instructions in order to link already known elements with new ones along the route (Nuhn and Timpf 2017). *Route knowledge* is gained when a traveler is exposed to a route. This also includes the knowledge of objects along the route. These objects can be divided in two groups: objects that were part of previous route instructions and objects that were not yet used for navigating. Route instructions, for a route segment part of route knowledge, can be coarser, i.e., merely enriched with additional landmarks (Tenbrink and Winter 2009). *Survey knowledge* is defined as the result of the mental integration of two or more routes (Herrmann et al. 1998). This is in contrast to route knowledge, which is related to a single route. If the traveler has never been to the environment and has never seen a map or photos then he has *no prior spatial knowledge* at all.

Personal Interests
Travelers must look around in order to perceive things. But looking by itself is not enough (Rensink et al. 1997). A traveler whose mind wanders during route following may often miss important objects, even if these are highly salient. The key factor for perceiving things is attention, which is dependent on the degree of interest (Rensink et al. 1997). Banerjee et al. (2015) confirmed that the voluntary focus of attention on environmental inputs is influenced by an observer's level of interest in an object. There are two types of interests: individual and situational interest (Hidi and Renninger 2006). Individual interests refer to an ongoing relation of a person to a particular content (Hidi and Renninger 2006). Situational interest describes interest that is caused by certain conditions and/or concrete features in the environment (Renniger and Su 2012). In this work we consider individual interests. It represents personality-specific orientation and provide important categories for action goals in a situation where a person is free to do as one pleases (Krapp et al. 2017). There are many different possible interests for a pedestrian in an urban environment. For example, a traveler, who is passionate about soccer but bored by historical monuments, will obviously be more attentive to soccer related things than urban features such as city walls or statues.

Personal Background
The personal background is a common name for attributes describing the traveler's experience outside of a specific domain (Brusilovsky and Millán 2007), in our case navigation and wayfinding. It gives information about the personal characteristics of a traveler and includes geographic data as well as data describing the traveler's characteristics (Kobsa et al. 2001). The *country of residence* is considered, because travelers not living in the country of the environment they need to navigate may be used to environments or objects shaped differently (Kattenbeck 2016). For example, if a Dutchman refers to recycling bins he maybe thinks of a tube-like object set into the ground (see Fig. 1, left) whereas a Frenchmen would search for a completely different object (see Fig. 1, upper right). The second geographically related attribute is the *cultural background* of the traveler. Travelers, who grew up in another country may be used to completely different environments and objects. For example, someone who grew up in a small village in Africa, where the next bigger city is several kilometers away, has a different background compared to somebody who grew up in the middle of a modern central European city. There are also attributes important for the multidimensional model concerning the traveler's characteristics. This includes the *education* of the traveler. It was revealed that users' knowledge in a domain varies considerably according to their background and job (Berry and de Rosis 1991). Concerning navigation and wayfinding, the education of a traveler can influence the way visual and structural dimensions are perceived (Kattenbeck 2016). Further attributes concerning travelers' characteristics are *gender* and *age* of the traveler. The incorporation of these attributes into this first proposal of a multidimensional model would require deeper analysis of their influence on the overall salience of a landmark, which is beyond the current scope of this paper. Nevertheless, we mentioned these attributes for the sake of completeness.

Fig. 1 Recycling bins in the Netherlands (left), France (upper right) and Germany (bottom right)

3.2 Calculating Salience

In this section the salience of the landmark attributes defined above is calculated. Methods for the calculation of salience for the attributes of all dimensions are investigated.

3.2.1 Salience of the Attributes of the Landmark Dimensions

In this section the salience for the attributes of each landmark dimension is calculated. We assign salience values to each attribute. If for a landmark candidate all attributes of a landmark dimension are salient it gets a 100% salience. For example, if an object meets all requirements of the structural dimension, it gets 100% for structural salience. The conditions that must be fulfilled in order to assign a percentage of a salience value to the attributes is shown in Table 1 and explained below.

Surface area and *color* are considered salient if their value is different from all others in a local environment. For the definition of this local environment a buffer of 100 m is chosen in this work. The *surface structure* is salient if the object has an outstanding surface (see Sect. 3.1.1). The assessment if the attribute value of *height* of an object is significantly different from mean characteristics within the buffer is done by hypothesis testing (see Raubal and Winter (2002) for details). As soon as the model is complete, a sensitivity analysis to identify the importance of the individual attributes of the visual dimension will be carried out. This will enable us to give different weights to different attributes. However, for the current study, we assume that each of the attributes of the visual dimension has the same effect on the overall salience of an object. Therefore, we assign a salience value of 25% if the attribute is salient. Zero percent means the attribute is not salient.

The attributes of the semantic dimension are salient if their attribute values are "True". Because the availability of explicit marks is of a higher value than cultural or historical importance it gets a salience of 50%. The other two attributes get a salience of 25%.

Table 1 Rules for the computation of landmark, descriptive and environmental saliences

Dimension	Attribute	Salient	Salience (Attribute)	Salience (Dimension)
Visual	Surface Structure λ	If λ = True	$s_\lambda \in \{0, 25\%\}$	$s_{vis}[\%] = s_\lambda + s_\phi + s_\mu + s_\gamma$
	Height ϕ	See text below	$s_\phi \in \{0, 25\%\}$	
	Surface Area μ		$s_\mu \in \{0, 25\%\}$	
	Colour γ		$s_\gamma \in \{0, 25\%\}$	
Semantic	Cultural importance ϵ	If True	$s_\epsilon \in \{0, 25\%\}$	$s_{sem}[\%] = s_\epsilon + s_\iota + s_\xi$
	Historical importance ι		$s_\iota \in \{0, 25\%\}$	
	Explicit marks ξ		$s_\xi \in \{0, 50\%\}$	
Structural	Number of adjacent routes η	If $\eta > 1$	$s_\eta \in \{0, 50\%\}$	$s_{str}[\%] = s_\eta + s_\theta$
	Number of adjacent objects θ	If $\theta = 0$	$s_\theta \in \{0, 50\%\}$	
Descriptive	Explicit marks D_e	If True	$s_{De} \in \{0, 100\%\}$	$s_{desc}[\%] = \max(s_{De}, s_{Dn})$
	Number of words D_n	dependent on the number	$s_{Dn} \in \{0, 50\%, 75\%, 100\%\}$	
Environmental	Advance visibility E_v	If visible	$s_{Ev} \in \{0, 25\%\}$	$s_{env}[\%] = s_{Ev} + s_{Eo} + s_{Ed} + s_{Eu}$
	Orientation E_o	If "in front" OR "beside"	$s_{Eo} \in \{0, 25\%\}$	
	Distance E_d	If $E_d = \min(D_{e1}, \ldots D_{ei})$	$s_{Ed} \in \{0, 25\%\}$	
	Uniqueness E_u	If True	$s_{Eu} \in \{0, 25\%\}$	

Concerning the structural attributes, the number of adjacent routes is salient if there is more than one route next to the object. Freestanding objects, where the number of adjacent objects is zero, are also significant. Similar to the case of visual attributes we assume that each of the attributes has the same effect on the overall salience and therefore assign a salience value of 25%.

3.2.2 Salience of the Attributes of the Descriptive Dimension

A landmark that can be described with an explicit mark is a valuable navigation aid and can be directly used in route instructions. Therefore such a landmark gets a salience for the explicit mark of 100% (see Table 1). If there is no explicit mark available the number of words is investigated. A landmark, which can be described with a single word is easy to remember for the traveler and therefore gets a salience for number of words of 100%. Descriptions with two terms are still easy to memorize but are more complicated than a one-word description. Therefore, such a landmark only gets a salience of 75% for number of words. Landmarks with descriptions including three words get a 50% salience. Landmarks with descriptions of more than three words get no salience for the attribute number of words, because they get too long.

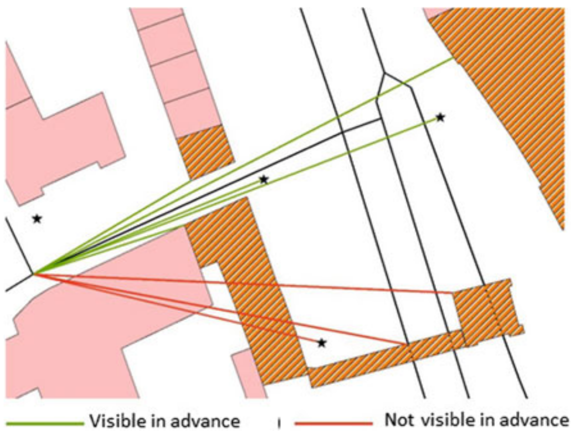
3.2.3 Salience of the Attributes of the Environmental Dimension

One attribute of the environmental dimension is *advance visibility* of a landmark (see Table 1). The implementation of Winter (2003) approach for visibility analysis would require deeper analysis of our data, which is beyond the scope of this paper. Therefore we use as a first step a simple line of sight analysis (see Fig. 2). It is investigated if the line of sight from the street intersection before the decision point intersects another object. If that is not the case then the attribute *advance visibility* is salient for this object.

Landmarks which are located next to or in front of the route get a salience of 25%. Landmarks at the back of the traveler are not as good as landmarks at the front or next to the route. Therefore, such a landmark gets no salience for *orientation*. Landmarks are useful navigation aids if they are close to the next decision point. Therefore, the object with the smallest distance to the decision point is assigned a salience of 25%. The other objects do not get any salience for this attribute.

The landmark is *unique* if there is no other misleading object within the environment of the route. Thus, neighboring street intersections are investigated. If there are no similar objects in one of these environments, a salience of 25% is assigned. For the environmental attributes the same applies as for the attributes of the visual and the structural dimension. We assume the same effect of the environmental attributes on the overall salience and apply a salience of 25% if it is salient. If it is not salient, the salience is zero.

Fig. 2 Example advance visibility



3.2.4 Salience of the Attributes of the Personal Dimensions

Landmarks should be selected according to the interests, background and prior spatial knowledge of the traveler. Each landmark belongs to a number of areas of interests. For example a city gate could belong to the areas of interests *historical monuments* and *architecture*. If an interest of the traveler matches one of the areas of interests that the landmark belongs to, then a significance value of 100% is assigned to the landmark (see Table 2).

For the attributes of the background dimension *country of residence*, *cultural background* and *education* are considered. The first two attributes are salient if the traveler has grown up or rather lives in the environment that she has to navigate. *Country of residence* and *cultural background* are attributes that are connected to each other. This means: if one attribute holds true the possibility is high that the other attribute also holds true. In order to avoid a higher weighting of these attributes compared to *education* only a salience value of 25% is assigned.

For education the same approach applies as for the interests. Hence, each landmark belongs to one or more educations. For example, measuring points are salient objects for surveyors. If the education of the traveler matches one education to which the landmark belongs, a significance value of 50% is assigned to the landmark. Which is as high as the salience values for *Country of residence* and for *cultural background* together.

The prior spatial knowledge is a dimension that influences most of the other dimensions and their attributes. For that reason the prior spatial knowledge is considered using weights within the multidimensional model. How the weighting is done is investigated in Sect. 3.3.2.

3.3 Overall Salience

In this section the overall salience of a landmark is determined. First, we calculate the overall salience using the conventional model by Raubal and Winter (2002). Secondly, we discuss our approach of the multidimensional model.

Table 2 Rules for the computation of personal saliences

Dimension	Attribute	Salient	Salience (Attribute)	Salience (Dimension)
Interest	Interest I	If I = I_{LM}	$s_i \in \{0, 100\%\}$	$s_I[\%] = s_i$
Background	Country of residence C	If C = True	$s_C \in \{0, 25\%\}$	$s_{PB}[\%] = s_C + s_B + s_E$
	Cultural background B	If B = True	$s_B \in \{0, 25\%\}$	
	Education E	If E = E_{LM}	$s_E \in \{0, 50\%\}$	

3.3.1 Conventional Model by Raubal and Winter (2002)

The approach from Raubal and Winter (2002) is also based on the well-established visual, semantic and structural dimensions. They include different attributes, which differ slightly from ours. However, we use our attributes (see Sect. 3.1.1), to make the models comparable.

Raubal and Winter (2002) determine in a first step values for each attribute. Then, it is investigated whether an attribute value is significantly different from the others. This is done using hypothesis testing. The significance value is set to 1 if there is a significant difference, i.e. the attribute is salient. Otherwise, the significance value is zero. We consider the attribute values as salient if they fulfill the conditions defined in Table 1 (column salient). For the salience values for the attributes we use also 1 and zero for the conventional model. Note, that this is a difference to our multidimensional model (see Sect. 3.3.2), where we use the salience values defined in Table 1 (column Salience (Attribute)).

Next, the significance values are grouped for visual, semantic and structural dimensions (see Eqs. 1–3). The total measure of landmark salience for each building is determined by adding up the grouped significance values (see Eq. 4). Raubal and Winter (2002) mentioned that the weights in this total measure can be used for an adaptation to the context or individual user preferences, but did not discuss this any further.

$$s_{vis} = (s_{\lambda} + s_{\phi} + s_{\mu} + s_{\gamma})/4 \tag{1}$$

$$s_{sem} = (s_{\epsilon} + s_{\iota} + s_{\xi})/3 \tag{2}$$

$$s_{str} = (s_{\eta} + s_{\theta})/2 \tag{3}$$

$$s_{convM} = w_{vis} * s_{vis} + w_{sem} * s_{sem} + w_{str} * s_{str} \tag{4}$$

3.3.2 Multidimensional Model

In this section we add the additional dimensions which we defined above to the conventional model of Raubal and Winter (2002) (see Sect. 3.3.1). Analog to their model the values for each attribute for each dimension are determined. Then, it is investigated whether an attribute value is salient. This is done according to the rules for the computation of saliences in Tables 1 and 2 (column salient). The attribute saliences are assigned according to Tables 1 and 2 (column Salience (Attribute)).

Then the significance values are grouped for visual, semantic and structural dimensions (see Table 1, column Salience (Dimension)). The same is executed for the environmental dimension (see Table 1, column Salience (Dimension)) and the background dimension of the personal dimensions (see Table 2, column Salience (Dimension)). To determine the overall salience value for the descriptive dimension the higher salience value of the attributes number of words and explicit marks is chosen. The interest dimension of the personal dimensions consists of only one attribute, therefore no further processing is needed.

Next, the overall salience value of an object is determined according to Eq. 5. The values for the weights are shown in Table 3. The weights represent the consideration of the prior spatial knowledge of the traveler within the multidimensional model. Travelers not familiar with an environment use landmarks which are highly visual salient (Quesnot and Roche 2015), therefore visual salience is weighted with a factor of 3. The semantic salience is zero because it is more appropriate for people familiar with an environment (Quesnot and Roche 2015). Structural salient landmarks should be used if there are no visual outstanding landmarks (Quesnot and Roche 2015), therefore structural salience is not as important as visual salience. For people not familiar with the environment explicit marks are not important, because it tells them nothing. Therefore, only the number of words is considered within the model. Because the environmental dimension, the interest and the background dimensions are important dimensions for selecting personalized route dependent landmarks they are weighted twice for all types of prior spatial knowledge (see Table 3).

$$\begin{aligned} s_{multidimM} = (&w_{vis} * s_{vis} + w_{sem} * s_{sem} + w_{str} * s_{str} \\ &+ w_{desc} * s_{desc} + w_{De} * s_{De} + w_{Dn} * s_{Dn} \\ &+ w_{env} * s_{env} \\ &+ w_I * s_I + w_{PB} * s_{PB})/100 \end{aligned} \tag{5}$$

A traveler with route knowledge is familiar with the route and therefore prefers landmarks that have a special meaning to him. Therefore, the semantic salience is weighted with a factor of 3. In this case the landmarks should also be describable by an explicit mark, therefore explicit marks are considered within the multidimensional model for route knowledge. Similarly to the other cases, the environmental and the personal dimensions are weighted with a factor of 2.

A traveler with survey knowledge should be familiar with the area. Nevertheless, it can be assumed that not all of the available landmarks are familiar because of their semantic salience but also because of their visual salience. Therefore, the visual as well as the semantic salience are weighted with a factor of 3. Structural salience

Table 3 Weights

Weights	No	Route	Survey
w_{vis}	3	0	3
w_{sem}	0	3	3
w_{str}	1	0	1
w_{desc}	0	0	1
w_{De}	0	1	0
w_{Dn}	1	0	0
w_{env}	2	2	2
w_I	2	2	2
w_{PB}	2	2	2

is also considered. In this case it is important if the object has a high descriptive salience no matter if this is because of a low number of words or an explicit mark.

4 Case Studies

4.1 Provenance of Data

The modeling of the landmarks in the multidimensional model requires a number of data sources. According to the defined attributes, visual, semantic, structural and descriptive data are required. In our case studies we used OSM data. The data not available from OSM (e.g. color or description) were collected through a field survey. The height of the buildings was extracted from a official 3D city model (block model). The height of the other objects was estimated manually for this preliminary study. For this paper we assume that the attribute values for the personal dimensions are available. In Sect. 4.3 possible methods to acquire the attribute values of the personal dimensions are discussed.

4.2 Personalized Landmarks—Examples

This section demonstrates the applicability and usefulness of the multidimensional model using three different case studies. In Fig. 3 an example decision point with 8 potential landmark candidates is shown. There are five buildings and three other objects. Within Table 4 the saliences for all the dimensions except the personal dimensions of the landmark candidates are listed.

In Table 5 the overall saliences based on Eq. 4, for the conventional model are presented. The results identify the recycling bins at the decision point as the most suitable landmark. Although the semantic salience of this landmark candidate is low, it has a high visual and structural salience (see Table 4). The next salient landmarks according to the conventional model are the streetlight and the casino. The streetlight is salient because it is freestanding. Whereas, the casino gets a high overall salience because of its semantics.

In the following sections we demonstrate the overall saliences based on Eq. 5 for different case studies for a traveler with no knowledge, survey and route knowledge. Note that, if there are landmarks part of landmark knowledge or part of previous route instructions available, theses landmarks should be used for route instructions. Then, no further investigations are needed. Therefore, in these example case studies we assume that neither landmark nor route knowledge (used in previous route instructions) landmarks are available.

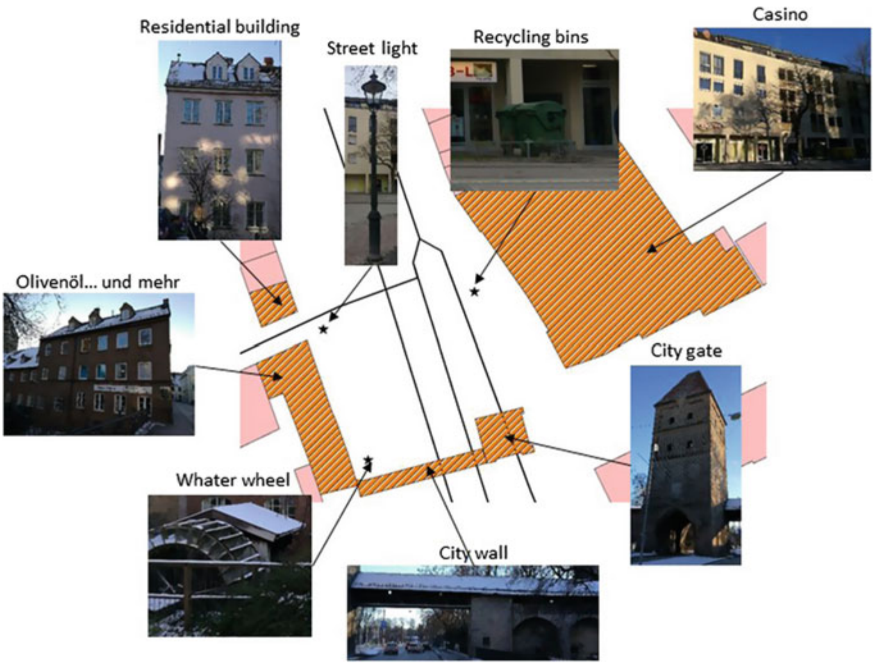


Fig. 3 Example decision point with landmark candidates

Table 4 Examples of object saliences (in percent)

Object	Visual	Semantic	Structural	Descrip.	Number of words	Explicit marks	Environm.
Olivenöl... und mehr	0	50	50	100	50	100	25
Residential building	0	0	50	75	75	0	25
Streetlight	25	0	100	75	75	0	50
Recycling bins	75	0	100	75	75	0	50
Casino	25	75	50	100	100	100	75
City gate	50	25	50	75	75	0	50
City wall	50	25	50	75	75	0	50
Water wheel	75	25	50	75	75	0	25

Table 5 Object saliences for a traveler with unknown interest and education

Object	No	Route	Survey	Conventional model
Oliven... und mehr	2.5	4	4.5	1.67
Residential building	2.75	1.5	2.75	1
Streetlight	4.5	2	4.5	2.25
Recycling bins	**6**	2	6	**2.75**
Casino	4.75	**5.75**	**7**	2.25
City gate	4.75	2.75	5.5	1.83
City wall	4.75	2.75	5.5	1.83
Water wheel	5	2.25	5.75	2.08

4.2.1 Traveler with Unknown Interest and Education

In Table 5 the overall saliences based on Eq. 5 are presented for a traveler with no, survey and route knowledge. These values are based on the attribute values of a traveler with unknown interest and education (Table 6). It is assumed that the traveler lives and has grown up within the country of the environment to navigate.

If we assume a traveler with no knowledge, the recycling bins would be the most suitable landmark (see Table 5), which is in line with the conventional model. This landmark shows a 75% visual salience, which is weighted with a factor of 3 (see Table 3). The water wheel also carries a visual salience of 75% but the environmental salience, which is weighted twice, is lower. The water wheel is located at the back of the traveler and has no advance visibility at all. Whereas the recycling bins are located in front of the traveler and are visible in advance. Also the structural salience

Table 6 Interest and background saliences for a traveler with unknown interest and education

Object	Interest	Country of residence	Cultural background	Education	Background
Olivenöl... und mehr	0	25	25	0	50
Residential building	0	25	25	0	50
Street light	0	25	25	0	50
Recycling bins	0	25	25	0	50
Casino	0	25	25	0	50
City gate	0	25	25	0	50
City wall	0	25	25	0	50
Water wheel	0	25	25	0	50

of the recycling bins is high, because they are freestanding objects. With regard to the number of words, which are considered to determine landmarks salience (see Table 3), only the casino is describable with a single word. The others need at least two words. Nevertheless, the recycling bins are the most salient landmark at the decision point, because the saliences of the other dimensions are high.

For someone with route knowledge the casino is a suitable landmark. The semantic salience is weighted with a factor of 3, while the visual and structural characteristics of a landmark candidate are not considered (see Table 3). For the determination of the salience of the landmark candidates in route knowledge areas it is considered if an object shows explicit marks. The casino is one of two landmarks (beside “Olivenöl... und mehr”) which shows explicit marks (see Table 4). Furthermore, the environmental salience is high, because the casino is visible early on while approaching the decision point, its orientation is “in front” and it is unique within the environment.

The best landmark for someone with survey knowledge would be the casino as well (see Table 5). To determine the landmarks in survey knowledge areas the visual and the semantic salience are weighted with a factor of 3 (see Table 3). Because the casino shows explicit marks it has a high semantic and a high descriptive salience as well.

4.2.2 Traveler with Interest in Historical Monuments

In this case study we assume a traveler who is a professor of cultural history and very interested in historical monuments. He also lives and has grown up in the country of the environment to navigate. In Table 7 the interest and background saliences for this case are shown. The city gate and the city wall get a salience for the interest and the background of 100%. The saliences of the landmark candidates dependent on these attribute values are shown in Table 8.

In this case, the most salient landmark for a traveler independent of his prior spatial knowledge are the city wall and the city gate. Because of the additional factor for the interest and the background their saliences are exceeding the saliences of the recycling bins (for no knowledge) and the casino (for survey and route knowledge). For a traveler with route knowledge the casino stays a good choice because it is highly semantic.

4.2.3 Traveler with Different Cultural Background

In this last case study we assume a traveler who has not grown up and does not live within the environment to navigate. This could be for example a tourist who is just for a few days within the city. In Table 9 the interest and background saliences for this case are shown. Recycling bins are often shaped differently in different countries (see Fig. 1). They can differ in form, size and color, therefore they get a value of 0 for *country of residence* and *cultural background*. Because the other buildings/objects

Table 7 Interest and background saliences for a traveler with interest in historical monuments

Object	Interest	Country of residence	Cultural background	Education	Background
Olivenöl... und mehr	0	25	25	0	50
Residential building	0	25	25	0	50
Streetlight	0	25	25	0	50
Recycling bins	0	25	25	0	50
Casino	0	25	25	0	50
City gate	100	25	25	50	100
City wall	100	25	25	50	100
Water wheel	0	25	25	0	50

Table 8 Object saliences for a traveler with interest in historical monuments

Object	No	Route	Survey	Conventional model
Oliven... und mehr	2.5	4	4.5	1.67
Residential building	2.75	1.5	2.75	1
Streetlight	4.5	2	4.5	2.25
Recycling bins	6	2	6	**2.75**
Casino	4.75	**5.75**	7	2.25
City gate	**7.75**	**5.75**	**8.5**	1.83
City wall	**7.75**	**5.75**	**8.5**	1.83
Water wheel	5	2.25	5.75	2.08

are the same in their appearance in different countries they get a salience of 25% for country of residence and for cultural background. The best landmarks for someone with no knowledge are the recycling bins or the water wheel (see Table 10). The water wheel has a low environmental salience, because the only attribute, which is salient of the environmental dimension, is the uniqueness. However, it has a high visual salience. In addition, it is an object that is shaped more or less the same in different countries. That makes the water wheel a good choice for someone with no knowledge for this case study.

The recycling bin is still a valuable landmark for someone with no prior spatial knowledge, although it has no salience for the personal background. But as already mentioned in Sect. 4.2.1, its visual, structural and environmental salience is high. For future work it is necessary to consider if landmarks with no *country of residence* or no *cultural background* salience should be excluded from the potential landmarks for the traveler.

Table 9 Interest and background saliences for a traveler with different cultural background

Object	Interest	Country of residence	Cultural background	Education	Background
Olivenöl... und mehr	0	25	25	0	50
Residential building	0	25	25	0	50
Street light	0	25	25	0	50
Recycling bins	0	0	0	0	0
Casino	0	25	25	0	50
City gate	0	25	25	0	50
City wall	0	25	25	0	50
Water wheel	0	25	25	0	50

Table 10 Object saliences for a traveler with a different cultural background

Object	No	Survey	Route	Conventional model
Oliven... und mehr	2.5	4.5	4	1.67
Residential building	2.75	2.75	1.5	1
Street light	4.5	4.5	2	2.25
Recycling bins	**5**	5	1	**2.75**
Casino	4.75	**7**	**5.75**	2.25
City gate	4.75	5.5	2.75	1.83
City wall	4.75	5.5	2.75	1.83
Water wheel	**5**	5.75	2.25	2.08

For someone with survey knowledge or route knowledge the casino is still (as in the two other case studies) a suitable landmark. The casino can be recognized by its explicit marks and is located in a normal building which has the same appearance in different countries.

4.3 Discussing Data Collection Methods for the Personal Dimension

In Nuhn and Timpf (2017) we discussed first methods to acquire the attribute values of the personal dimensions. A possible method to capture the prior spatial knowledge of the traveler is to store already navigated routes. Also, landmarks that were already used for navigation could be stored as landmarks part of *landmark knowledge*. The attribute values for the personal background must be provided explicitly because it is nearly impossible to deduce them by sensors or by simply watching the traveler. The personal interests of a traveler can be learned with the help of a learning system (see also Richter 2017) because entering all the values explicitly would be too exhausting and time consuming for a traveler.

There are still attributes of the personal dimensions missing (for example, gender and age of the traveler) which we have to include in our model. As soon as the model is complete a sensitivity analysis to check the models logic and robustness will be carried out. The identification of the importance of the individual attributes enables to estimate the effort which must be invested in data acquisition for different attributes. If the sensitivity analysis indicates that the model includes a number of attributes to which the model is insensitive, then we can maybe exclude these attributes from our multidimensional model to minimize the acquisition effort.

5 Conclusion and Future Work

This paper proposes a multidimensional model for landmarks that incorporates landmark, descriptive, environmental and personal dimensions. The dimensions of the model and their attributes were defined and debated. Further, methods for the calculation of salience for the attributes of all dimensions were investigated. Finally, the dimensions were integrated in a multidimensional model to calculate the overall salience. We showed that varying attribute values for the attributes for the personal dimension changed the most salient landmark in our case studies. In this paper, weights were chosen based on consideration. This provides a good framework for an empirical study in a real usage context to fine-tune the current approach.

In this paper, first ideas on how to consider the traveler's interests were proposed. In this work we considered the interest of a person to a particular content. In future work we will also consider interest that is caused by certain conditions such as the goal of wayfinding. Further attributes concerning travelers' background are gender and age of the traveler. In this paper we neglected these attributes because their incorporation in the multidimensional model would require deeper analysis. In future work we will investigate their influence on the overall salience of an object.

In this paper we provided an example how to consider a traveler with different cultural background. But there are also people with multi-cultural background. For example someone who grew up in a small village in Africa and then moved to a central European city is used to differently shaped objects with the same meaning. So we have to investigate the question after which period of time such a person is familiar enough with the city that he is also able to use country-specific objects for navigation.

References

Balaban CZ, Röser F, Hamburger K (2014) The effect of emotions and emotionally laden landmarks on wayfinding. In: Proceedings of the 36th annual conference of the cognitive science society, pp 1880–1885

Banerjee S, Frey HP, Molholm S, Foxe JJ (2015) Interests shape how adolescents pay attention: the interaction of motivation and top-down attentional processes in biasing sensory activations to anticipated events. Eur J Neurosci 41(6):818–834

Berry DC, de Rosis F (1991) Designing an adaptive interface for epiaim. In: Mario S, Arie H, Marius F, Jan T (eds) AIME 91, Springer, pp 306–316

Brusilovsky P, Millán E (2007) User models for adaptive hypermedia and adaptive educational systems. In: Peter B, Alfred K, Wolfgang N (eds) The adaptive web. Springer, pp 3–53

Burnett G, Smith D, May A (2001) Supporting the navigation task: characteristics of 'good' landmarks. In: Hanson MA (ed) Contemporary ergonomics 2001, Taylor & Francis, pp 441–446

Caduff D, Timpf S (2005) The landmark spider: Representing landmark knowledge for wayfinding tasks. In: Barkowsky T, Freksa C, Hegarty M, Lowe R (eds) AAAI spring symposium: reasoning with mental and external diagrams: computational modeling and spatial assistance. AAAI Press, pp 30–35

Caduff D, Timpf S (2008) On the assessment of landmark salience for human navigation. Cog Process 9(4):249–267

Duckham M, Winter S, Robinson M (2010) Including landmarks in routing instructions. J Locat Based Serv 4(1):28–52

Elias B (2003) Extracting landmarks with data mining methods. In: Kuhn W, Worboys MF, Timpf S (eds) Spatial information theory. COSIT 2003. Lecture notes in computer science, vol 2825. Springer, Berlin, pp 375–389

Elias B, Sester M (2006) Incorporating landmarks with quality measures in routing procedures. In: Raubal M, Miller HJ, Frank A, Goodchild MF (eds) Geographic information science. GIScience 2006. Lecture notes in computer science, vol 4197. Springer, Berlin, pp 65–80

Götze J, Boye J (2016) Learning landmark salience models from users route instructions. J Locat Based Serv 10(1):47–63

Hamburger K, Röser F (2014) The role of landmark modality and familiarity in human wayfinding. Swiss J Psychol 73(4):205–213

Herrmann T, Schweizer K, Janzen G, Katz S (1998) Routen- und überblickswissen - konzeptuelle überlegungen. Kognitionswissenschaft 7(4):145–165

Hidi S, Renninger KA (2006) The four-phase model of interest development. Educ Psychol 41(2):111–127

Kattenbeck M (2016) Empirically measuring salience of objects for use in pedestrian navigation. PhD thesis, University of Regensburg, Chair for information science

Klippel A, Winter S (2005) Structural salience of landmarks for route directions. In: Cohn AG, Mark DM (eds) Spatial information theory. COSIT 2005. Lecture notes in computer science, vol 3693. Springer, Berlin, pp 347–362

Kobsa A, Koenemann J, Pohl W (2001) Personalised hypermedia presentation techniques for improving online customer relationships. Knowl Eng Rev 16(2):111–155

Krapp A, Hidi S, Renninger A (2017) Interest, learning and developement. In: Ann R, Suzanne H, Andreas K (eds) The role of interest in learning and development. Psychology Press, pp 3–26

Lovelace KL, Hegarty M, Montello DR (1999) Elements of good route directions in familiar and unfamiliar environments. In: Freksa C, Mark DM (eds) Spatial information theory. COSIT 1999. Lecture notes in computer science, vol 1661. Springer, Berlin, pp 65–82

Lynch K (1960) The image of the city. MIT press

McGillivray S, Murayama K, Castel AD (2015) Thirst for knowledge: the effects of curiosity and interest on memory in younger and older adults. Psychol Aging 30(4):835

Nothegger C, Winter S, Raubal M (2004) Selection of salient features for route directions. Spat Cogn Comput 4(2):113–136

Nuhn E, Timpf S (2016) A multidimensional model for personalized landmarks. In: International conference on location based services. Austria, Research Group Cartography, Vienna University of Technology, Vienna, pp 4–6

Nuhn E, Timpf S (2017) Personal dimensions of landmarks. In: Bregt A, Sarjakoski T, van Lammeren R, Rip F (eds) Societal Geo-innovation: selected papers of the 20th AGILE conference on geographic information science. Springer International Publishing, pp 129–143

Nuhn E, Reinhardt W, Haske B (2012) Generation of landmarks from 3D city models and osm data. In: Gensel J, Josselin D, Vandenbroucke D (eds) Proceedings of the AGILE 2012 international conference on geographic information science, pp 365–369

Palmiero M, Piccardi L (2017) The role of emotional landmarks on topographical memory. Front Psychol 8:763

Quesnot T, Roche S (2015) Quantifying the significance of semantic landmarks in familiar and unfamiliar environments. In: Fabrikant SI, Raubal M, Michela B, Davies C, Freundschuh S, Bell S (eds) Spatial information theory. COSIT 2015. Lecture notes in computer science, vol 9368. Springer, pp 468–489

Raubal M, Winter S (2002) Enriching wayfinding instructions with local landmarks. In: Egenhofer MJ, Mark DM (eds) Geographic information science. GIScience 2002. Lecture notes in computer science, vol 2478. Springer, Berlin, pp 243–259

Renniger AK, Su S (2012) Interest and its development. In: Ryan RM (ed) The Oxford handbook of human motivation, OUP USA, pp 167–190

Rensink RA, O'Regan JK, Clark JJ (1997) To see or not to see: the need for attention to perceive changes in scenes. Psychol Sci 8(5):368–373

Richter KF (2017) Identifying landmark candidates beyond toy examples. KI 31(2):135–139

Richter KF, Winter S (2014) Landmarks—GIScience for intelligent services. Springer International Publishing

Schneider LF, Taylor HA (1999) How do you get there from here? mental representations of route descriptions. Appl Cogn Psychol 13(5):415–441

Siegel AW, White SH (1975) The development of spatial representations of large-scale environments. Adv Child Dev Behav 10:9–55

Sorrows ME, Hirtle SC (1999) The nature of landmarks for real and electronic spaces. In: Freksa C, Mark DM (eds) Spatial information theory. COSIT 1999. Lecture notes in computer science, vol 1661. Springer, Berlin, pp 37–50

Tenbrink T, Winter S (2009) Variable granularity in route directions. Spat Cogn Comput 9(1):64–93

Thorndyke PW (1980) Spatial cognition and reasoning. In: Harvey JH (ed) Cognition, social behavior, and the environment, Rand Corporation, pp 137–149

Waller D, Loomis JM, Golledge RG, Beall AC (2000) Place learning in humans: the role of distance and direction information. Spat Cogn Comput 2(4):333–354

Winter S (2003) Route adaptive selection of salient features. In: Kuhn W, Worboys MF, Timpf S (eds) Spatial information theory. COSIT 2003. Lecture notes in computer science, vol 2825. Springer, Berlin, pp 349–361

Winter S, Raubal M, Nothegger C (2005) Focalizing measures of salience for wayfinding. In: Meng L, Zipf A, Tumasch R (eds) Map-based mobile services theories, methodsand implementations. Springer, pp 125–139

Winter S, Janowicz K, Richter KF, Vasardani M (2012) Knowledge acquisition about places. SIGSPATIAL Spec 4(3):20–21

Wolfensberger M, Richter KF (2015) A mobile application for a user-generated collection of landmarks. In: Gensel J, Tomko M (eds) Web and wireless geographical information systems. W2GIS 2015. Lecture notes in computer science, vol 9080. Springer International Publishing, pp 3–19